FALL AND EARLY WINTER INJURIES TO ORCHARD TREES AND SHRUBBERY BY FREEZING.

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Agricultural Experiment Station.

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BULLETIN 192.

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FIG. 1.—Section of arborvitae screen, south farm, Ohio Agricultural Experiment Station, Wooster, injured by October freeze 1906. These shrubs are 6 to 8 feet high in the section shown in the picture. The two trees at the extreme ends and the third tree from the right hand end survived in fairly good condition—the remainder dead or almost dead; Photographed November, 1907.

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FALL AND EARLY WINTER INJURIES TO ORCHARD TREES AND SHRUBBERY BY FREEZING.

BY A. D. SELBY.

THE QUESTION STATED.

The matter of injury to orchard trees and ornamental shrubs from freezing during the fall and winter of 1906–7, has been presented by many examples, including several species and varieties of plants. These examples have been found in great abundance over almost the whole of the state; exception is to be noted chiefly in the orchard areas along the "lake shore" district wherein the cases were quite infrequent.

The injured tree or shrub at times failed to grow in spring except from near the base, as with Weigela, privet and occasional peach trees; in other instances, as with evergreens, especially with arborvitae, there was no early spring indication of injury unless upon critical examination with the knife, which was seldom made; but later in the season, especially in mid-summer, the leaves began to turn brown and show an unhealthy appearance. When critical examination was made at this time the bark was found to be cracked throughout much of its length, and the injured trees died in whole or in part toward the close of the summer. (See Figure I.)

With orchard trees of tender age, especially under five years from transplanting, and more particularly with apple and peach trees, some of the trees died to the ground while others put out new leaves and made some growth, only to suffer later from sudden wilting, in whole or in part, followed by dying off at the top and other symptoms as from lack of moisture. Still other examples showed but limited apparent injury as judged by growth or leaf symptoms during the summer, although these trees formed sprouts near the base of the trunk and in certain cases showed serious lack of vigor in a part of the branches near the end of the season. Such injured trees as yet retained considerable vitality showed, when examined closely, certain dead and depressed or cracked portions of the bark of the trunk of sufficient extent and seriousness to explain the other symptoms of injury; the same dead and cracked areas of less distinct outline showed upon trees that had collapsed in mid-summer. (Figures 2, 3 and 4.)

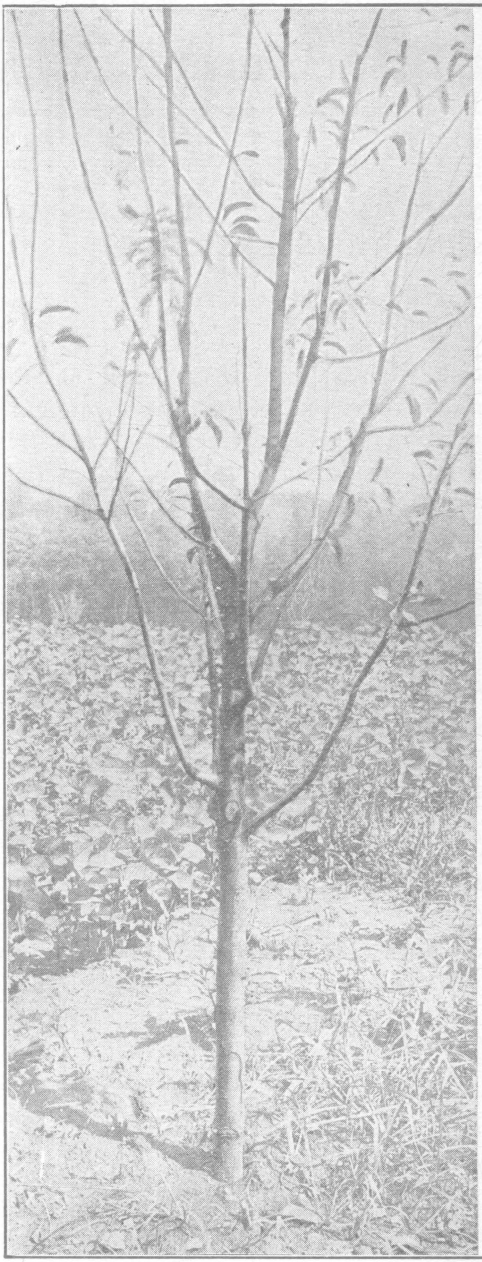

FIG 2.—Rome Beauty tree, 4 years old. Southeastern test farm, Carpenter, in cultivated portion. This tree shows large lesion near the base with corky enlargement below the lesion, but no sprouting. Tree showing very low vitality when photographed, July 20, 1907.

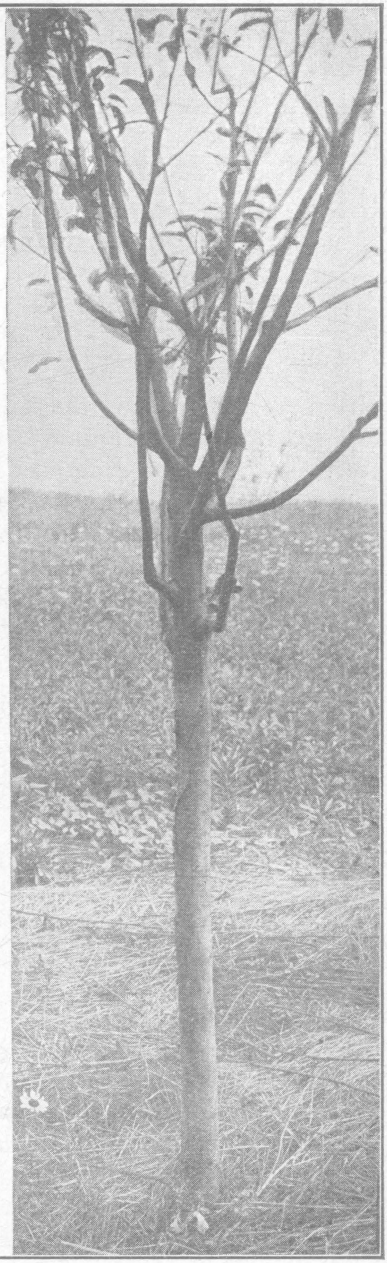

FIG. 2.—Same variety and source as Fig. 2, but in sod mulch. This tree shows injury throughout much of its trunk and the enlargement of the living portion producing ridges around borders of dead area on trunk Photographed July 20, 1907.

Upon certain varieties of plum, notably Burbank, Abundance, and Wickson, not always hardy, the "die back" of the branches was most marked; in some instances this extended for two or three feet from the end of the branch and in others, branches four to five feet long were killed to the union with another branch, while a few were killed entirely. Such trees commonly made a vigorous growth from adventitious buds and comparatively few of them were a total loss. English walnut trees in Scioto county were killed back almost entirely to the trunk or major branches.

Along with these described conditions in apple, peach and plum, other trees and shrubs suffered injury similar in kind, but varying in degree or extent, and these have all given rise to inquiries that have been the basis of study by the writer. The public interest seems to justify the publication of the results of the studies made.

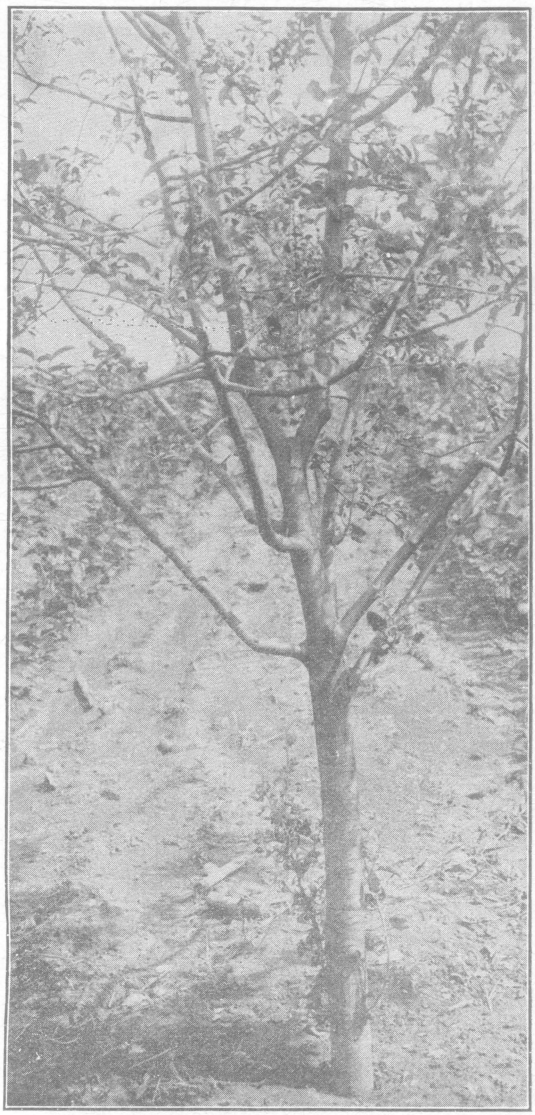

FIG. 4.—Jonathan tree, 4 years old, Southeastern test farm Carpenter, in cultivated portion. Tree of vigorous previous growth with small lesion near base of trunk and sprouts from below. Photographed July 20, 1907.

NATURE AND EXTENT OF THE INJURY.

The injuries to apple trees showed first in brown color of the inner bark. This brown color becomes more pronounced as the branch dies. It frequently happens that a rather limited area

on the trunk is injured; in such cases only this area dies and the growth of the surrounding parts goes on as usual. Often this growth is so great in amount and the increase in the size and diameter of the trunk is such that cracking of the outer bark occurs on the line between the dead and living areas of the trunk. Whether the difference in rate of enlargement is enough to produce cracking about the area, or whether it is not, the injured portion shows by being depressed below the surrounding parts. This depressed appearance of the injured or dead areas, together with the dull and dead outer bark, makes the discovery of such parts rather easy, but if one uses a knife and simply scrapes off the outer bark, the dead and brown bark below will readily show the differences between the various portions of the trunk and whether free from injury. These differences between injured areas and uninjured or healthy parts of the trunk show many gradations between one form and another; See illustrations Figs. 2, 3, 4.

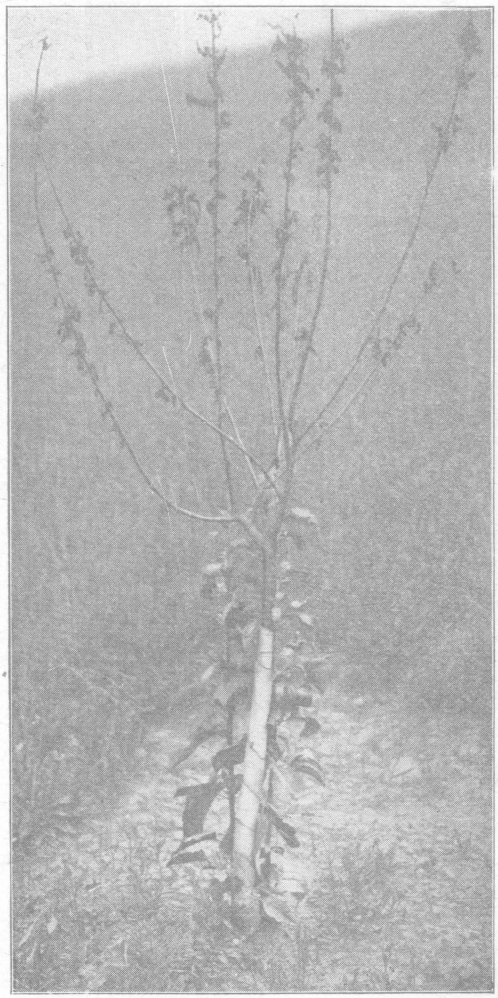

FIG. 5.—Rome Beauty tree 2 years old, Dr. Crawford's orchard, Clinton Furnace (Quinn P. O., Scioto Co., O.) This shows typical tree in sod killed by freezing; these trees had been neatly wrapped with strips of manilla paper to protect from rabbits. Local workmen assigned this wrapper as cause of injury, but there is no evidence to support such claim. Photographed July 1, 1907

Where the injury is rather slight upon a vigorous tree, as in Figure 4, adventitious shoots or sprouts grow out below and the apparent injury to the trunk is not very large. However, the trunk is seriously injured in such cases and will be a long time healing up by new growth from around the border of such a dead place on the trunk. One illustration, figure 2,

shows how the growth about the base of the injured area has produced conspicuous enlargement.

The injuries on the trunks of apple trees are usually upon the most exposed side of the tree. In Trumbull county, northeast to northwest portions of the trunk were most often injured. At Carpenter, Meigs county, the injured areas represented every point of the compass upon the Rome Beauty variety. Upon the

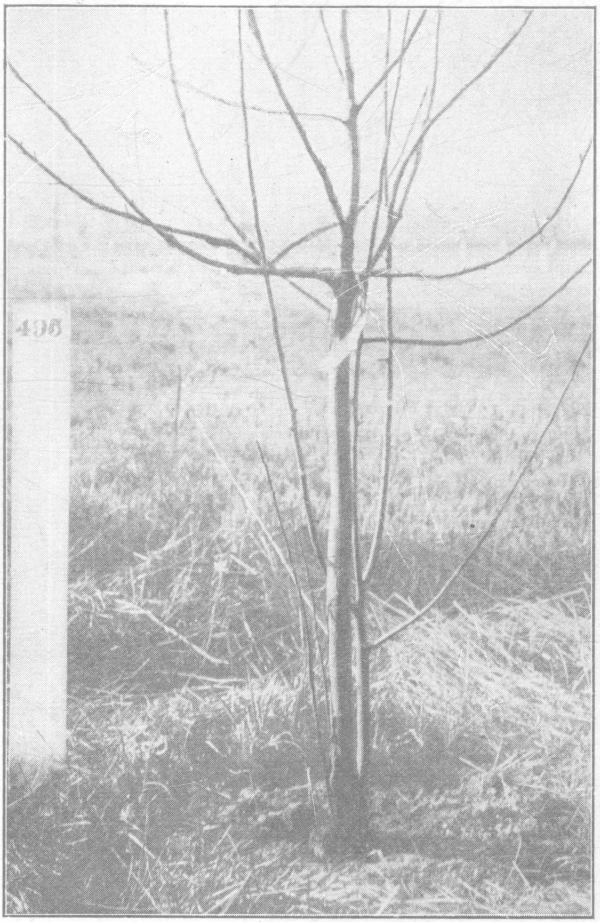

FIG. 6.—Gravenstein (Banks) 2 years old, O. A. E. S., Wooster, showing serious injury of trunk on northeast exposure which broke off above sprouts. Photographed Nov., 07.

Jonathan the small localized spots were very largely on the west or southwest parts of the trunk and near the base. With smaller and weaker trees the freezing more often killed the trees down to a protecting line, such as a cover of snow which occurred in Trumbull county. A closely applied mulch might serve the same purpose. See figures 5, 6, 7 and 8.

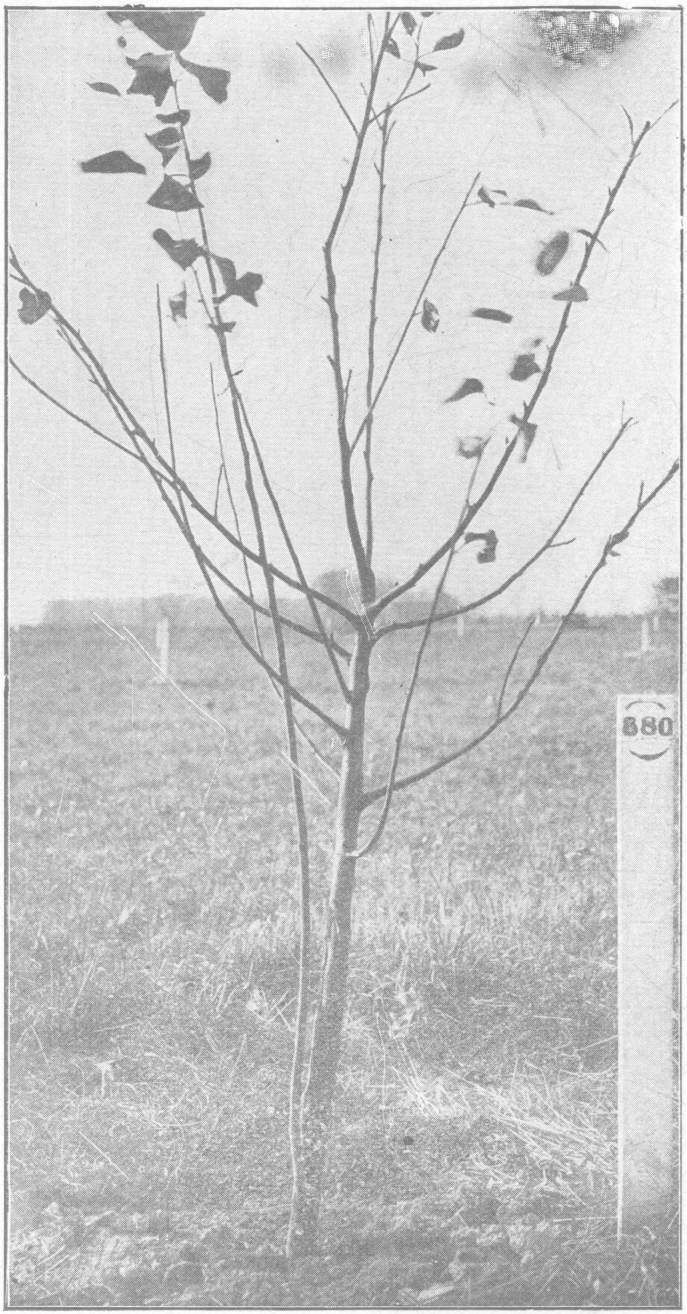

FIG. 7—Dutch Mignon (Chico Co., Cal.), tree 1 years old, O. A. E. S., Wooster, very badly injured on Northeast exposure with vigorous shoot. Photographed, November, 07.

In two-year-old apple trees at the Station, Wooster, the injury was very serious upon trees of several varieties growing in the sod mulch. but showed in cases of partial injury almost exclusively upon the north and northeast portions of trunk. It is to be noted here that, aside from all other observations made at at an early date that might for this reason go to fix the time of the injury to the tree, *the direction from whence the cause of the injury came bears quite satisfactory evidence.*

FIG. 8—Newtown Pippin tree, 2 years old, O. A. E. S., Wooster, seriously injured on Northeast exposure. Nothing can save trunk so badly Injured; new trunk possible from sprout. Photographed Nov. 07

"Sun scald" as we commonly call it upon large orchard trees, is a well known form of injury from winter freezing; sun scald is quite uniformly upon the south and southwest exposures of the tree trunks. The explanation is found in the fact that the *temperature rise upon these sun-exposed surfaces is larger* than upon less exposed portions, and accordingly the danger of stimulus to untimely activity of the living layer is *much greater* upon the heated side.

Bearing this in mind we can probably discriminate between the more usual freezing injuries in mid-winter upon tree trunks in orchards and the unusual injuries of October, 1906. Four–year–old cherry trees at Ashville, Pickaway county, also showed in November, 1907, a limited number with a dead strip running up and down the north exposures of the trunk. Mr. E. E. Richards definitely observed in October of 1906, in Clermont county, cracked trunks of fruit trees due to October freeze. These observed conditions will again be referred to further on.

The extent and number of injured apple trees was very striking upon Dr. W. I. Chamberlain's farm, Hudson, Summit county,

young apple trees both in old and new orchards were three to five years of age in sod mulch and chiefly of the Baldwin variety. 80 to 85 per cent or possibly 90 per cent were so seriously injured as to be a total loss. Grimes and one or two other sorts were slightly less injured than the Baldwin trees. At the Experiment Station, at Wooster, trees two years of age and under were very badly injured. On one year old trees of Mr. F. L. Allen, Kinsman, Trumbull county, about 80 to 85 per cent of the Baldwin trees were lost, while perhaps 40 to 45 percent of the Jonathan were injured. Upon two year old Northern Spy trees the proportion of seriously injured ran much lower, possibly about 20 percent. Mr. Allen informs me that when these were top-grafted later in the spring the brown inner bark above required the trees to be cut down sometimes within two or three inches of the ground before safe wood was reached in either the one-year-old or two-year-old Northern Spy trees. Mr. Allen pointed out also that the lower limit of injury was marked by the snow-line from two to six inches above the surface of the ground. Such a snow was on the ground during the October freeze and the injuries to the trees became evident late in February. Here the evidence points to the October freeze as the cause of the injuries. Serious winter freezing injury occurred in the young apple orchards at Carpenter, Meigs county, on the southeastern test farm of the Station, where all of the Rome Beauty variety were a total loss, also upon young orchard trees in Fairfield county, particularly upon the orchards of Mr. Chas. H. Ochs, and Mr. John Huffman his neighbor in Pleasant township. Serious winter injuries likewise occurred in Pickaway county, upon various fruit trees including Japan plum, sour cherry and upon raspberries; also in Ross county, and especially upon young apple trees in Scioto county. In the two and three year old trees of Dr. J. N. W. Crawford, Clinton Furnace, Scioto county, set in pasture sod, about one-third to one-half were destroyed and an additional portion were more or less injured.

Of such injured trees only the most seriously injured failed to leaf out in the spring, while the larger portion formed leaves and the initial growth which results from the stored food in the trunk and and branches of the trees. Some trees made even more growth and some survived through the season. All seriously injured trees died somewhat suddenly as if from lack of water. Indeed quite a few growers hauled water to apply about the trees, but all this was without avail.

Upon shrubbery, tender plums, and raspberries, as before stated, the injury took the form of killing back. Upon arborvitae

the proportion of injured trees was usually less than 40 percent and often not above 5 to 10 percent. The actual injured area seemed to extend throughout the length of the trunk, and most of the trees did not die until August or September. The trunk usually showed cracking open on the line between injured and uninjured portions.

THE INJURIES NOT CONFINED TO OHO.

In conversation with Prof. L. R. Taft, Horticulturist of the Michigan Experiment Station, during the meetings at Lansing in May, 1907, he mentioned the fact that injuries had been observed in portions of Michigan. Professor Taft, under date of November 8, 1907, very kindly reports as follows his observation upon the injuries in Michigan during the fall and winter:

"Your letter regarding the effect of the freeze of October, 1906, is at hand. I am quite surprised to learn of the serious results in Ohio. In Michigan very little harm was done, except to peach trees, outside a strip of about 20 miles wide and extending some 60 miles north from the Indiana line, along Lake Michigan. North and east of this section a good many of the young peach trees were killed and some harm was done to the older peach trees, but in all of the northern counties they had the largest crop of peaches ever grown in that section. In the southern and eastern parts of the state some injury was done to raspberries, tender shrubbery and peach trees, but I have seen no harm whatever to apples, pears, plums and grapes, except, perhaps upon low, wet land where they were making a late growth.

In the "Frozen Region," however, the peach trees were practically wiped out, not more than 10 percent remaining. These, of course, are in very poor condition. Japanese plums, sweet cherries and some varieties of apples and pears were also injured, especially the young trees and where they were making a late growth

I know a man who lost two thousand nine-year-old apple trees, (500 each of Baldwin, York Imperial, Hubbardston and Grimes Golden), and in the same orchard, practically no harm was done to the Duchess, Wealthy, Yellow Transsparent and Jonathan. This, you will note, reverses the relative injury to York Imperial and Jonathan as reported by you.

In Michigan the injury was observed almost at once and at the meeting of the State Horticultural Society, which took place the first week in December at Benton Harbor, in the midst of the "Frozen Region," the reports were very general that the trees had been killed."

Yours very truly,

L. R. TAFT, Horticulturist.

KINDS OF TREES INJURED; VARIETAL DIFFERENCES IN APPLES.

The writer has made no observations in the peach district of Ottawa county, and has received no reports of unusual injury. In many parts of Trumbull, Ashtabula and Mahoning counties young peach trees set less than three to four years were wholly killed by freezing, and limited injuries to young peach trees over almost the

whole of the interior portion of the state have been reported. See Figure 9. Young apple trees have suffered most seriously unless ornamental shrubbery will offer equally general injury.

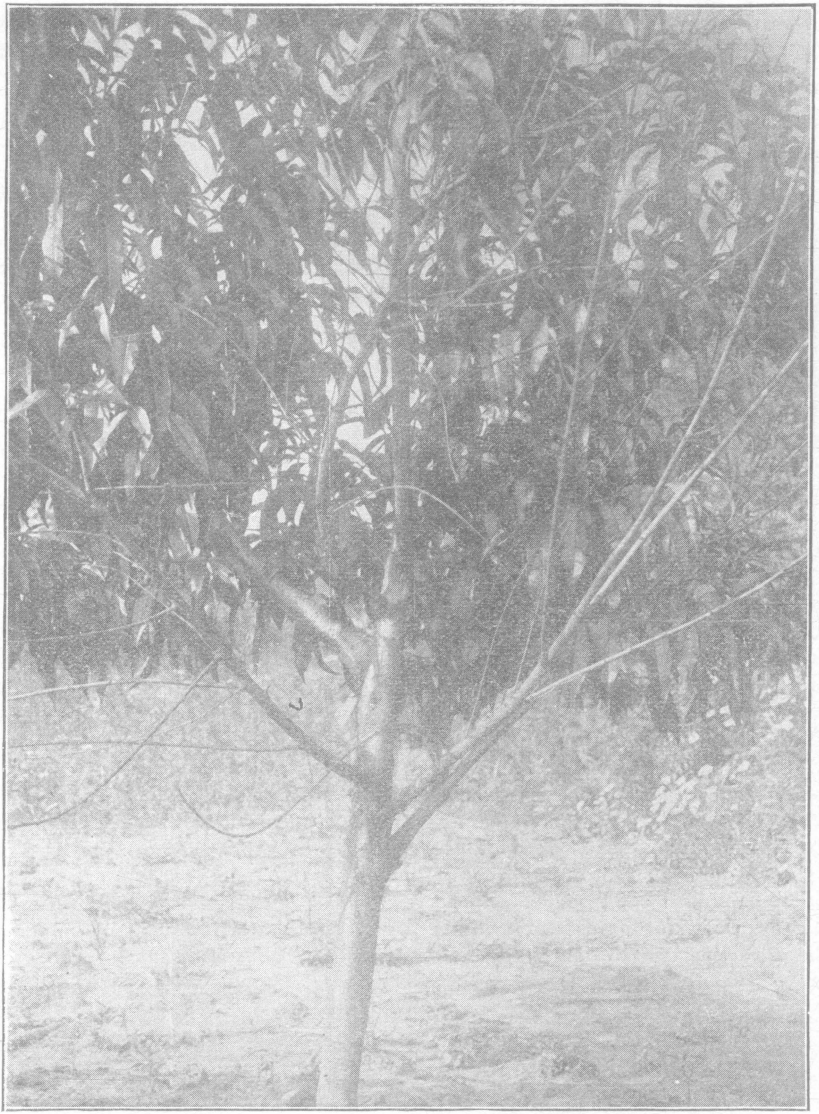

FIG. 9—Peach tree 2 years old, Southeastern Test Farm, Carpenter. Figure shows one of remaining trees, most of them being killed. This one injured by freezing on one side; dead branches and ridge along line of living growth shows evidence of the injury. Photographed July 20, 1907.

In Pickaway county, Mr. L. H. Ward, of Ashville, reports that he noticed that many blossom buds on his Keiffer pear trees were brown and dead as early as December, 1906. Subsequently more of the

buds were injured by the mid-winter freezes and there were no blossoms upon the trees, which were about five years of age.

Apple trees have been injured over such a wide area as to call forth many letters of inquiry. The western third of the state has reported very limited injury as compared with the remainder, but over the greater portion of Ohio, trees less than five years of age suffered very seriously. Arborvitae, privet, Weigela and ornamental shrubs were frozen back, as was English walnut at Portsmouth. Some rose bushes suffered in a similar manner.

The list would therefore include the following:

Apple (young), plum (Japan), sour cherry, peach, raspberry, Weigela, privet, English walnut and arborvitae.

As already hinted great difference was noted in the injury upon the different commercial varieties of apples. In the northern part of the state the Baldwin variety suffered worst, while in the southern part the Rome Beauty was most susceptible, unless Hubbardston has suffered equally. It has been noted that 80 to 85 percent of the Baldwin trees five years of age and under were a total loss at Hudson. Also that 80 to 85 percent of one year old Baldwin trees were lost at Kinsman, in Mr. Allen's orchard, while less than half of the Jonathan were seriously injured. In Fairfield county, Mr. Ochs lost much more heavily in the Rome Beauty; his statistics bearing date of November 18, 1907, are as follows:

Record of number of each variety of apples planted and number lost by freezing in orchard of Chas. H. Ochs, Lancaster, Ohio.

Variety	No. planted	No. lost
Baldwin	160	20
Grimes Golden	150	16
Jeffries	50	2
Hubbardston Nonsuch	20	12
Ben Davis	50	1
Gano	50	0
Jonathan	100	1
York Imperial	50	0
Rome Beauty	200	109
Stark	50	3

These were in sod mulch. Mr. Ochs's neighbor, Mr. J. C. Huffman lost 115 trees out of 640; distributed as follows:

Variety	No planted	No. lost
Rome Beauty	200	100
Hubbardston Nonsuch	20	15

In the four-year-old orchard at the Southeastern Test Farm, Carpenter, Meigs county, partly in sod mulch and partly under cultivation in cover crops, the following were the results of injury by freezing:

Variety	Number planted	Number lost or seriously injured
Rome Beauty	96	96
Jonathan	8	5
York Imperial	48	2(?)
Peach trees	220	about all

Alongside these trees of Rome Beauty, Jonathan trees of the same age, in cultivation, were injured only 10 to 15 percent, while York Imperial suffered no very notable injury.

In Scioto county, the Clinton Furnace orchards of Dr. J. N. W. Crawford, consist only of Rome Beauty, so no comparison between varieties could be made; there 40 to 50 percent of the trees were destroyed. At the Station, Wooster, about the following injuries occurred; about 175 trees were planted of about 75 varieties; of these approximately 60 are dead or seriously injured.

Mr. Edward R. Minns, of Coalburg, Mahoning county, reports a loss of 20 two-year-old Grimes trees by freezing in 1906-7 out of a total of 102, and of 10 Jonathan trees out of 99 in all and *exclusively in the sod mulch.* Additional trees were slightly injured; Wealthy and Duchess were injured in the same block. The reason for this variation in the amount of injury on the different varieties will be discussed under the next heading.

CONDITIONS AND CAUSE OF THE INJURY.

Until about August 1, the season of 1906 was one of rather low temperature and more than the average rainfall, except in the western part of the state. We were studying at the Station the prospects of an outbreak of late blight of potatoes, (*Phytophthora*) and were following the season's changes very closely. August and September were much warmer than usual. The Ohio Weather Bureau reports August as the warmest for fourteen years except in 1900, and the rainfall was the heaviest for many years, or since 1888. September was similar to August, being unusually warm and exceeded by only three other Septembers, 1888, 1895 and 1900. Indeed the mean temperature for the month was about three and one-half degrees above the normal. The rainfall was about normal, so that growth incited by the heavy rains and high temperatures of August continued almost throughout the month of September.

The temperature for the first eight days of October was quite high, followed by very sudden cold weather October 10 to 12, without any preparatory or ripening frosts.

The result was unprecedented late growth, both in amount and duration, upon young apple trees. The heavy rains already mentioned in August led to the same vigorous growth in sod as in cultivated orchards, or almost the same; possibly in some instances the growth in sod was rather later than under culture.

All this new growth, without the checking effects of frost or leaf dropping, showed the usual character of new growth with the sap layer or cambium full of water, gorged with water in fact, and

the cells in process of multiplication, as always happens in growing twigs. *Such water-gorged, growing cells were in no condition to resist cold or to protect themselves fully from low temperatures by evaporation of water from the tree surfaces.*

While these seasonal adjustments or readjustments are annually taking place, horticulturists may at times overlook them, or miss the principles involved. With woody stems and branches the preparation for winter involves, first of all a marked reduction in the amount of water in the parts; this is a result, more or less direct, of the slowing down of growth. The diminished growth commonly is induced by the lower temperatures normally prevailing in September, and is aided by diminished rainfall at that period of the year. A very hasty study of the mean monthly precipitation for Ohio, page 144 will show how these averages shrink in amount from July to October. The inevitable result of excessive rainfall, as in July and August of 1906, would be to produce unusual growth and *much more would be induced under the higher temperatures which then prevailed.*

To carry the matter further: In case of seeds the low temperatures these can withstand when comparatively dry is most astonishing. The writer experimented in 1901 with seeds of several plants which had been subjected to the very low temperatures of approximately —190° Fahr. by prolonged immersion in liquid air. Yet after these very low temperatures the germination percentages were almost normally good.

We do not expect the same normal resistance to freezing in woody stems that we find in dry seeds, yet under average conditions we are justified in expecting that the process of ripening, as we call it, or better, of getting rid of excess water content, will take place in advance of normal cold weather. The finding of trees injured by freezing accordingly calls for an explanation of the injury.

Mention has been made of loss of trees situated in low ground. Here the cause of susceptibility may be two-fold: First, the trees may fail to mature the wood by reason of late growth. Second, in case of very low temperatures in mid-winter the soil being full of water is compactly frozen and the water supply to the branches is cut off for that reason at the roots.

Under normal circumstances most growth of apple twigs ceases by early September or even by an earlier date. The cells cease to multiply and there is that gradual loss of water in the cambium or sap layer, which always marks the so-called ripening of the wood. At the same time, no new leaves being formed, the older leaves cease to work and give up to the young branches the starch or other food

materials which they contain. With this ripening of the parts in the normal season usually come light frosts after September 1, so that the leaves drop off and the trees are prepared for winter. What a difference between normally matured twigs and trunks and the twigs and trunks of 1906! For be it remembered that when the new shoots are growing and are soft and sappy this same condition applies to the sap layer or cambium ring around the trunk all the way to the ground. Indeed the twigs and branches have no other way to be supplied with moisture except through the conducting parts of the trunk, and the formation of new cells, which takes place when the trees grow, would occur over the whole tree.

With this October condition of young trees that would normally occur in early September, we had a cold period October 10 to 13, in which temperatures sank to a low level, high winds prevailed, snow storms occurred and the apple trees were as if moved from summer conditions into this freezing cold wave. While the actual minimum was not uncommon the cold came unusually early in the month and spread itself about the phenomenally immature conditions that have just been described.

All the evidence so far collected in Ohio, together with that obtained from Michigan, points to the October freeze as the cause of the injury upon many of the young trees in the state.

In addition to these conditions of the fall the winter minimum temperatures were quite low, −15°F. for December, −23°F. for January, and −19°F. for February; moreover these were preceded by open, sunny and rather unusually *warm periods for winter.* This would seem to offer the explanation for such injury as may have occurred in *mid-winter* upon the sun exposed side of the trunks of trees. The very warm January weather will be noted from the table further on.

WHY SOME VARIETIES OF APPLES SUFFERED WORSE THAN OTHERS.

The principal reason why some varieties suffered worse than others from freezing is found in the difference in the maturity of the growth. The less vigorously growing varieties of apples usually make this growth early in the season and it is not continued much beyond midsummer. On the other hand very vigorously growing sorts like Baldwin continue growing normally much later in the season and would, therefore, be readily influenced by the exceptional conditions of August and September of 1906. The growth continued very late in the case of "Rome Beauty" which suffered seriously in southern Ohio; the variety is slow, too slow, to start its growth in the spring, and for the same reason tardy in ripening its

growth in the fall. The Rome Beauty would also continue to grow under the conditions of August and September. Other trees that made earlier growth and matured or ripened earlier would show very different response to the conditions. This continued late growth with many varieties leaves an immature sap layer or cambium made up of multiplying cells gorged with water. Indeed it has been pointed out not only in resistance to freezing but in resistance to fungus diseases that varieties with lower percentages of water are less easily attacked by the parasite than those with higher content.

In the matter of the varieties of apples, despite this liability, the Baldwin is a favorite variety for the northern portion of the state, and the Rome Beauty is the prize cold storage variety of southern Ohio. Both have suffered this serious freezing injury. We can not at this time regard this liability as a fatal weakness. Apparently the conditions were so unusual in 1906 that there is no strong reason to fear an immediate repetition.

INJURIES COMPARED WITH THOSE OF MIDWINTER IN OTHER YEARS.

Winter injuries of the type due to freezing and premature death of the cambium layer are not rare, even with hardy fruit trees, although less frequent with apple than with peach, pear, plum, etc. In the "lake belt" and locally in many parts of the state the writer has studied local losses at various times due to freezing. In these cases the conditions were peculiar to the particular orchard injured and not general for a large district or for the whole state. European varieties of plum and less commonly cherry trees are attacked by the shot-hole or leaf-spot fungus, *Cylindrosporium padi*, and thus lose their leaves prematurely, especially in rainy seasons. Plum trees are often stripped of their leaves in August and following such loss of leaves new growth and frequently new blossoms are produced. In the fall of 1896 the loss of foliage on plum trees was very great in orchards not carefully sprayed. Two such orchards in Ottawa county, one situated near Elmore, the other at Lacarne, were studied the following year.* Nearly 50 percent of the Elmore orchard was practically destroyed by the subsequent freezing. In the orchard at Lacarne the general loss was perhaps less although some varieties suffered even a larger loss, the younger trees being killed even to the snow line.

*Bulletin 111; 117 and 118.

COMPARISON OF THE SEASON OF 1906-7 WITH THE AVERAGE SEASON.

NORMAL MEAN MONTHLY TEMPERATURES AND RAINFALL FOR OHIO, ALSO MINIMUM AND MEAN MONTHLY TEMPERATURES AND RAINFALL FOR 1906-07 AND 1880-81.

Months	Temperatures									Rainfall		
	State Average of 23 Years				1906			1880		Av. for 23 years	1906	1880
	Normal Mean	Min.	Date	Year	Mean	Min.	Date	Mean	Min.	Mean		
	Degrees	Degrees			Degrees	Degrees		Degrees	Degrees	Inches	Inches	Inches
May	61.2	19	21	1895	61.3	24	10	65.8	35.5	3 63	2.17	1.24
June	69.7	29	6	1894-95	69.8	34	2	63.4	45.5	3.94	3.41	5.65
July	73.9	34	9	1895	72.1	43	25	74.5	52 0	3.37	5.14	6.06
August	71.5	31	22	1895	74.6	43	28	71.	48.0	3.04	4.77	5.03
September	65.5	23	29	1887	68.9	36	15	64 8	41.5	2.71	2.92	2 02
October	53 5	8	30	1895	52.7	18	12	52.3	30.5	2 13	3.19	2.27
November	40.9	—8	29	1887	41.1	14	16	33.9	—5.0	3.05	2.59	2.39
December	31.1	—32	19	1884	32.3	—15	24	25.7	—13.0	2.74	3.68	1.06
					1907			1881			1907	1881
January	27.8	—34	25	1884	32.2	—3	27	24 2	—2.0	2.70	6.11	1.31
February	26.8	—39	10	1899	26.0	—19	6	29 0	—2.5	2.66	,85	3.25
March	38.8	—17	20	1883	45.9	—2	4	35 6	13.	3.39	55 5	2 75
April	49.7	6	3	1899	42.5	10	2	44.8	14.	2.75	2.74	2.47

As earlier noted, August and September, 1906, were very warm, while August had a high rainfall. The minimum temperature for October was not as low as it has been in other years, although it came very early in the month. The winter minimum temperatures were not unusual.

The difference between trees attacked in this way as by some leaf parasite and the young orchard trees of 1906, *lies only in the cause of the late growth.* In 1896 it was a parasitic fungus attacking the leaves of plum trees; in 1906, the cause lay in the unusual weather conditions causing growth of many kinds of trees followed by premature freezing in October. In both cases just mentioned the real condition which resulted in injury was the newly formed water-gorged tissue, which was not in a condition to resist freezing.

An earlier example of the destruction of young orchard trees in winter is supplied me by Director Thorne. This occurred in the winter of 1880–81 upon the farm of Mr. D. N. Hine, Berlin Heights, Erie county. One orchard of Baldwin trees with a few Grimes, all 7 or 8 years old, had been overrun with fall grass and had received late cultivation; as a consequence of this and perhaps influenced by moderate temperatures with heavy rainfall in August, and only normal rainfall in September, heavy and prolonged growth occurred in the orchard. The subsequent winter was marked by zero weather toward the end of Noyember, and the record of minus thirteen degrees (–13°F.) for December; it caused total destruction of the Baldwin trees, some of which even burst open, with practically no injury to the Grimes. A second orchard of ten acres composed entirely of Baldwin of the same age, was entirely killed by the winter freezing. These orchards were situated in Berlin township, Erie county, on sandy soil about three miles from the lake shore.

It would seem that the loss of young apple trees in the winter of 1906 is anomalous or unusual only in its widespread character over the state. The conditions of the loss or preceding it were doubtless very unusual.

THE INJURIES CONSIDERED IN RELATION TO ORCHARD PRACTICE.

It will be noted from the case just cited that in these young Baldwin orchards of 1880–81, unwise, late cultivation brought about the late growth and the failure of this growth to ripen in preparation for winter. It might accordingly be expected that the freezing injuries of 1906–7 would show a difference between cultivated orchards and those in the sod mulch. The case cited at Carpenter, Meigs county, where all the Rome Beauty trees were a total loss, irrespective of whether in cultivated land or sod mulch, shows this not to be true in that orchard. The apple trees under the one method of cultivation seemed to grow as late and be as little prepared for winter as in the other. We might ordinarily expect that apple trees in sod mulch would complete their growth earlier than in cultivated land, but the heavy rainfall in July and August, and the moist, warm

conditions of September 1906 brought about just as much late growth in the sod orchards as in the cultivated ones. Indeed we may recall that the spring of 1906 was cold but evidence is lacking that delayed growth in the spring was associated with late growth in the fall, although this is not entirely improbable. The loss of trees in Dr. Chamberlain's orchard at Hudson shows this to be true as does that of Mr. Ochs, Fairfield county, and of Dr. Crawford's in Scioto county. Mr. Minns reports dying of the sod mulch trees but does not state whether same sorts were in other lots. The writer can find little evidence that one method of orchard practice left young orchard trees in much better condition to resist freezing than did another in the summer and fall of 1906.

On the other hand Mr. Ward, of Ashville, had the different varieties of plum trees planted in rows which included both sod land and land cultivated in corn. While the injuries were negligible in the sod land, except on one variety of plum, the Wickson, in the cultivated land the three varieties, Burbank, Abundance and Wickson suffered severely. This is in line with extended experience as for example the case given for 1880-81.

Another phase of orchard practice, viz, that of the method of tree propagation to be pursued, may not offer so slight a difference in injury as seems to have been the case with cultivated and mulched lands. The susceptibility of the Baldwin, the Rome Beauty and the Hubbardston varieties to conditions that incite late growth and then subject them to the risk of freezing injury is not one that may wisely be settled by planting other sorts exclusively. At any rate the present state of our knowledge would not justify any such advice as to refrain from planting two such varieties as the Baldwin is in northern Ohio, and as the Rome Beauty has shown itself in the southern portions. The facts rather suggest the question of what may be done by methods of propagation to lesson the risks involved in growing orchards of these varieties till they reach the bearing age and become more immune from risk of freezing injury. While Baldwin is a good grower from the nurseryman's point of view the Rome Beauty is not so easily started.

For southern Ohio, therefore, it may be worth while to produce the tops of this variety upon the trunks of some other sort which is less susceptible to late growth conditions. This is likely to assist only during the early period when the risks seem to be the greatest. From the data now at hand Gano and Ben Davis have shown little susceptibility to winter injury and are usually satisfactory from the standpoint of growth; the same applies to York Imperial and possibly to Jonathan.

SECONDARY CONSEQUENCES TO TREES INJURED IN 1906-7.

The writer is convinced that the indirect results of this freezing injury may be observed for many years to come upon apple trees which show rather slight effects in the way of minor lesions or even such slight dead areas as may be now entirely overlooked.

First of all there is danger from wound-fungi that produce rotting of the trunk and result in such weakness that a storm would break off the trunk.

In the second place the dead areas would impair the flow of water from the roots to the branches and cause one-sided development of the top. It would often be preferable to produce a new top from a shoot at the base than to run these risks. At the same time it must be admitted that fungi may attack the dead stump at the base and finally result in root rot.

The Station Botanist is very anxious to keep in touch with orchardists whose apple trees have suffered in the manner described in this bulletin and thus to complete the records of these possible secondary effects where the trees were left standing.

CONCLUSIONS.

1. The evidences of serious loss to fruit growers from freezing injuries in the fall of 1906 and the winter of 1906-7 are most conclusive. The losses are most conspicuous upon young apple orchards five years old or less from transplanting. The percentage of seriously injured trees runs very high and with certain varieties is astonishingly large.

2. Of varieties of apples the Baldwin in the northern part of the state where this variety is largely planted, and the Rome Beauty and the Hubbardston in the southern portion have suffered most seriously. In some instances 90 percent or more of the young trees of these standard varieties have been seriously injured by freezing.

3. The actual time of the freezing injury has not been precisely determined although the evidence points to the October freeze of 1907 as the chief period of loss. Warm mid-winter weather together with low minimum temperatures in winter render it probable that some injury occurred during the winter's cold.

4. It is suggested that the exposure of the portion of the trunk injured offers evidence as to the actual time of the injury. Injured areas of a northerly exposure seem to be attributable to the cold weather of October 1906.

5. A study of the conditions which prevailed during the autumn of 1906 shows that the temperature and rainfall were both much above the average for August, while the temperature was still greatly above the normal for September and the early days of October.

6. Such abnormal conditions would inevitably result in late growth of the vigorous or belated growing types of trees, as with certain varieties of apples, and would tend to bring about similar conditions with all young trees and with tender shrubbery. This would be accompanied by all the phenomena of immaturity, namely, excessive water content of the new growth and of the cambium of the trunk together with inability to protect these tissues from the effects of cold.

7. The resultant injuries from freezing were of all the usual types, including killing back, total destruction, and local dead areas on the trunks of the injured trees. The explanation of these injuries is held to be found in the precedent conditions of immaturity of the parts as stated above.

8. There is not sufficient evidence of a kind to show advantage for one method of orchard practice over another as a means of warding off such winter injury. The heavy losses with standard varieties of apple suggest the possibility of growing these sorts upon trunks of another variety.

9. While winter injuries are by no means uncommon, the causes are usually local and peculiar to isolated orchards. The loss by freezing in 1906-7, however, seems to be the result of abnormal climatic conditions of the sort above summarized, and *may accordingly be regarded as unusual both in the time of its occurrence and in the severity with which certain types of trees were injured.*

10. We may safely conclude that if a protective covering is applied as a mulch to guard against freezing in winter, such covering may not safely be applied as early as September without risk in seasons like that of 1906.

11. It is believed that secondary effects upon apple trees injured by freezing may be observable for several years and orchardists are invited to communicate to the Station Botanist any further observations along this line.